THE POST-PLEISTOCENE ELEVATION OF THE INYO RANGE, AND THE LAKE BEDS OF WAUCOBI EMBAYMENT, INYO COUNTY, CALIFORNIA.

THE following notes are the result of observations made in the summers of 1894 and 1896. My routes were: first, from Alvord Station on the Carson and Colorado Railroad eastward on the Saline Valley road, passing through Waucobi Canyon and over the divide seventeen miles E. S. E. of Alvord; second, from Alvord through Soldier Canyon, over the range to Deep Spring Valley.

As seen from the foothills of the Sierra Nevada, looking across Owens Valley, the axis of the low portion of the Inyo-White Mountain Range, between Soldier Canyon and the ridge south of Waucobi Canyon, arches strongly to the eastward, and forms a broad embayment between Soldier Canyon on the north and the head of Waucobi Canyon on the south. (Fig. 1.) The range from east of the divide at the head of Owens Valley to Owens Lake is practically one, but unfortunately it has been given the name of White Mountain to the north and of Inyo Range[1] to the south of the embayment. Inyo is here used to include the range south of Soldier Canyon. For the broad embayment formed I use the name Waucobi, and for the ancient lake in which the lake beds were deposited the name Waucobi is also adopted. It was the examination of the lake beds deposited in Waucobi embayment that led me to conclude, from their position, that a marked orographic movement had taken place in the Inyo Range since Pleistocene time.

In crossing Owens Valley, from Alvord Station eastward, the lake beds are met with about a mile and a half east of the station, at an elevation of 100 feet above the railroad track. (*a*, Fig. 2.) They extend north of this point along the western

[1] Am. Jour. Sci., March 1895, 3d series, Vol. XLIX, p. 169.

foot of the White Mountain Range for fifteen miles or more. Near Black Canyon they occur well up the slopes, and traces of them were seen north of a line passing through Bishop Station; to the south they appear for a short distance beyond the entrance to Waucobi Canyon. As seen from Alvord Station, the

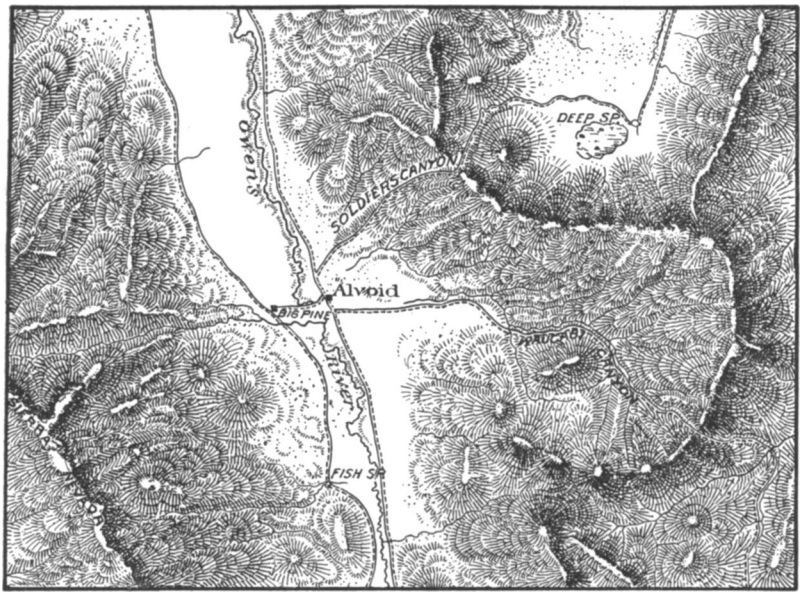

FIG. 1. Map showing the general relations of Soldier and Waucobi Canyons to Owens Valley and the Inyo Range. (Taken from Lieutenant Wheeler's map.)

beds extend from the south side of Waucobi Canyon north across the broad embayment to Soldier Canyon, and westward from three to ten miles, rising with the slope to the foot of the encircling ridge of Cambrian quartzites. (*b*, Fig. 2.) The beds at the Devils Gate in Waucobi Canyon are 2250 feet above the lowest bed exposed east of Alvord, and appear to be the same as those at the lower level; they extend on up the canyon to a level 3100 feet above the valley bottom at Alvord Station and within about three miles of the summit (below *c*, Fig. 2) at the head of the canyon.

The strata of the lake beds section three miles up the canyon are largely a fine calcareous deposit, with more or less arenaceous and argillaceous matter in the form of fine sand. Some of the white beds are made up almost entirely of the remains of fresh-water shells of the following genera, as identified by Dr. W. H. Dall: Valvata, Planorbis, Pisidium ?, and possibly Amnicola and Pampholyx. The species are undetermined, but resemble *Valvata sincera* Say and *Planorbis parvus* Gld. "Any of them might be recent or Pliocene; my impression from the mass is that they are Pleistocene."

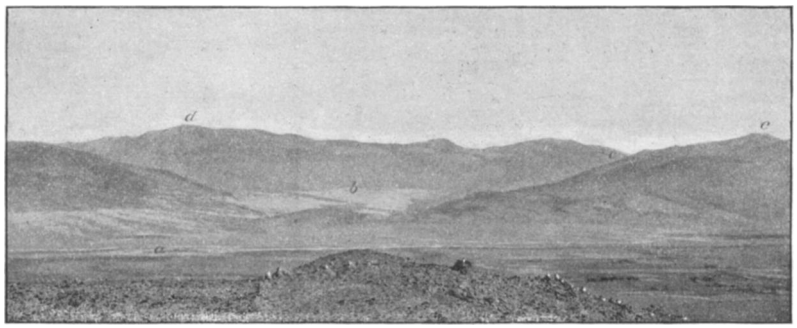

FIG. 2. View of Waucobi embayment from the foothills of the Sierra Nevada. *a* Lake beds at the level of Owen's Valley; *b*, contact of lake beds with the Cambrian quartzites; *c*, point above the highest exposure of the lake beds in Waucobi Canyon; *d*, point of Inyo Range overlooking Deep Spring Valley on the east; *e*, Waucobi Mountain south of Waucobi Canyon.

As the beds approach the steeper slope of the mountain, about ten miles above the mouth of Waucobi Canyon, the sediments become coarser and coarser, and brown arenaceous beds predominate over the drab and light gray sediments. Near the contact with the quartzites, a little below Devils Gate, bowlders of the quartzite a foot or more in diameter occur in the coarse sediments, and the contact of the lake beds and the Cambrian quartzites is finely shown on the south side of the canyon.

At a point about two miles above Devils Gate, and 3000 feet above the lowest lake bed observed in Owens Valley, there is a

fine exposure on the south side of the Saline Valley road, which is the highest seen in the canyon that might be referred without doubt to the lake beds. The band exposed is about six feet in thickness, formed of layers of white, very finely granular sediment, which crumbles under strong pressure. It is capped by

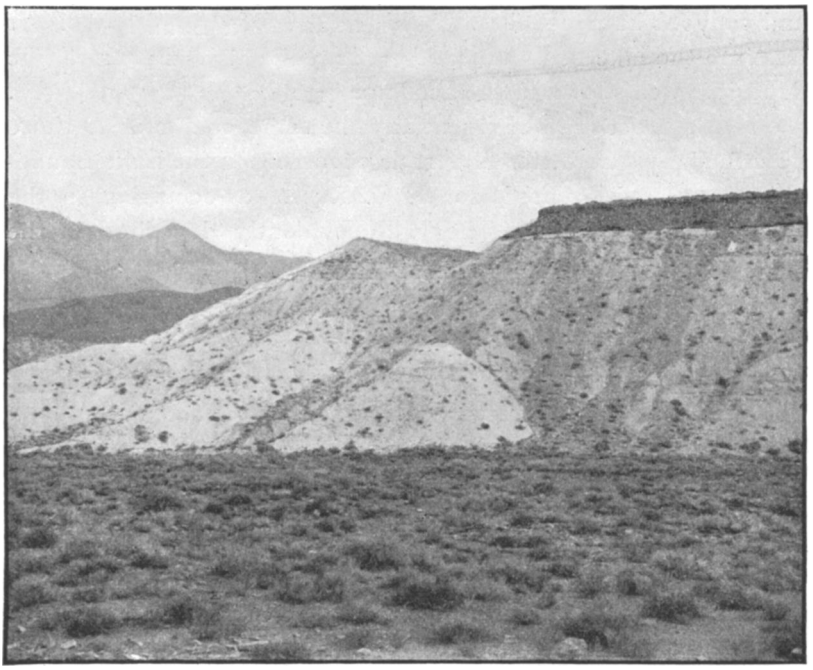

FIG. 3. Lake beds, Waucobi Canyon, Inyo Range. About five miles above Owens Valley. The dark Cambrian rocks of the White Mountain Range north of Soldier Canyon are shown on the left upper half of the plate.

layers of fine conglomerate formed of small angular fragments of quartzite.

The greatest thickness of the beds observed at any one point was estimated at 150 feet. The finer, light colored calcareous beds vary from sixty to seventy-five feet in thickness. Near the valley the average dip is 3° to 5°. About two miles up it increases to 10° for a short distance and then changes to from

3° to 5° in its continuation up the canyon. The rise of the canyon bottom is nearly coincident with that of the lake beds.

The upper surface of the lake beds throughout the Waucobi embayment is covered by a layer of débris formed of fragments of arenaceous limestone, siliceous shale, and quartzite that have been brought down from the mountain slopes. Numerous washes and canyons have cut through this mantle of drift and more or less into the lake beds beneath. The general character of the deposit is well shown in the accompanying figure (Fig. 3).

The lake beds are of essentially the same character as those described by Mr. G. K. Gilbert as occurring in the Lake Bonneville basin, and by Professor I. C. Russell as occurring in the Lake Lahontan basin.[1] They were evidently deposited in the bottom of a lake, into which, near the shore line, coarse material was washed from the mountains, the finer sand and silt being carried farther out and deposited with the calcareous sediment and remains of fresh-water shells.

There may be no *a priori* reason why such deposits should not have been made upon a lake bottom sloping from 3° to 5°, but this is improbable, and it would presuppose the existence of a lake 3000 feet in depth over the site of the present Owens Valley. If such a lake existed, there must have been a barrier to the south of Owens Lake, of which no trace now remains. This is not at all probable. South of Owens Lake the divide is about 220 feet above the lake.[2] There is no appearance, as viewed from the south end of the Inyo Range, of the remains of a great barrier between Owens Lake and the drainage basin to the south.

A second conception is that the Inyo Range has been elevated, the range and the country to the eastward rising and tilting the lake beds toward Owens Valley and the Sierra Nevada.

The accompanying diagrammatic sketch (Fig. 4) illustrates the relations of the Sierra Nevada, Owens Valley, the Inyo Range, and the lake beds resting on the westward slope of the Waucobi embayment.

[1] Mon. U. S. Geol. Survey, Vols. I and XI.

[2] Owens Lake, 3567 feet above sea level; Hawai meadows, 3782 feet at divide. Wheeler).

The view of the lake beds taken from the foothills of the Sierra Nevada, looking eastward across Owens Valley, shows the lake beds at *a*, Fig. 2, at the level of the valley, and various outcrops from point to point toward the foot of the mountain at *b*.

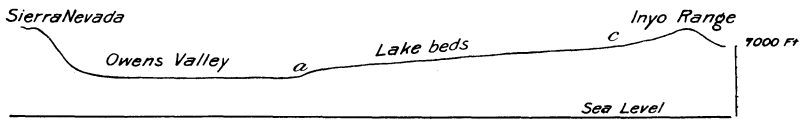

FIG. 4. Diagrammatic outline section from the Sierra Nevada to the summit of the Inyo Range, a little north of Waucobi Canyon.

The lake beds continue up Waucobi Canyon to a point approximately beneath the letter *c*, where, as previously stated, they are 3000 feet higher than the lowest beds at *a*.

The view includes the greater part of the Waucobi embayment, but does not extend on the north (left) as far as Soldier Canyon. The high point at *d* forms the summit of the ridge east of the Waucobi embayment and overlooks Deep Spring Valley to the northeastward. This part of the range, from *d* to the head of the Waucobi Canyon above *c*, forms the eastern portion of the block which appears to have been tilted toward the base of the range at *a*. On the northeastern side the slope of the range extends down to the level of Deep Spring Valley. It was on the southeastern side of this valley that I found evidence of a comparatively recent fault which is of great interest in connection with the view that the Inyo Range has been raised to the eastward and tilted to the westward within comparatively recent times. The best locality at which to examine the fault line is on the southern side of the valley, at a point about seventeen miles north of the head of Waucobi Canyon. Here there is evidence that the bottom of the valley is sinking in relation to the mountains on the southeastern side. This is shown by the presence of a comparatively recent fault scarp at the foot of the ridge and the truncating of the spurs along the base of the ridge where the fault scarp is not otherwise defined. Great springs flow out along the line of the fault, and Mr. Lewis Payson informed me that he had been unable to find bottom, by any

means at his command, in the large pools into which the springs flow, and that where wagons formerly crossed, at the southeastern end of the flat surrounding the springs, animals are frequently mired in the soft mud of the flat. The fault cuts through the Pleistocene, leaving a northward-facing wall from twenty to thirty feet in height overlooking the pools and bogs. A distant view of the ridge on the southeastern side of the valley is shown in Fig. 5. The fault scarp mentioned is directly beneath *a*, and the extension of the fault crosses the ridge a little to the right of *a*.

The eastern slopes of the Inyo Range ten miles south of Waucobi Canyon, and south of the road which passes east from the divide to Saline Valley, are very steep and join the bottom of Saline Valley as abruptly as the ridge on the southeastern side of Deep Spring Valley meets the level valley bottom. (Fig. 5.) Until a good topographic map of this region is made, it will be impossible to trace and connect the relations of the various faults and evidences of comparatively recent disturbance; but I think that there is sufficient evidence in the sinking of the southern margin of Deep Spring Valley, in the phenomena observed to the south in Saline Valley, and in the position of the Waucobi lake beds, to sustain fairly well the view that the range has been elevated to the eastward and tilted to the westward.

The total amount of the uplift cannot be accurately determined, as there was undoubtedly a slope at the bottom of Waucobi Lake from its margin toward the present site of Owens Valley. It was probably not much greater than, if as great as, the elevation of the present divide south of Owens Lake, which is about 220 feet. It is to be borne in mind, however, that perhaps in the tilting of the range the western edge under Owens Valley has been depressed, and that the valley has been silted up by the wash brought down by the river and from the adjoining mountains, quite as rapidly as, if not more rapidly than, the tilting of the Inyo Range has carried down the floor of the valley. If this is correct, the total elevation of the range since the lake beds were deposited may be as great as or greater than the difference in the

level of the lake beds at the margin of the valley and the highest point in Waucobi Canyon, or 3000 feet. There are so many factors that might be considered with more data, that only an approximation can now be made of the total displacement. We are justified, I think, in placing it at about 3000 feet, and

FIG. 5. View of southeastern portion of Deep Spring Valley, showing pond near spring, and the north face of the ridge that extends northeastward from the Inyo Range. *a*, Position of fault cutting through the ridge; *b*, southwestern end of the ridge where it unites with the Inyo Range.

thus recording the fact that a movement of considerable magnitude has occurred. That the movement is comparatively recent is proved by the characters of the lake beds and their contained fossils, which indicate the age of the deposits to be late Pliocene or Pleistocene.

It is interesting to note in this connection the account of the earthquake that occurred in Owens Valley in 1872. This earthquake, according to Professor J. D. Whitney,[1] originated in Owens Valley, and its occurrence was accompanied by a sinking of strips of land. Mr. G. K. Gilbert visited Owens Valley eleven years later, and in his observations on the subject he says

[1] The Owens Valley earthquake. Overland Monthly, Vol. IX, 1872, pp. 130–140 and 266–278.

that "the principal scarp produced by the earthquake follows the base of the alluvial foot slope of the Sierra Nevada, and has a maximum height of about twenty feet. Where this height is attained there is a companion fault scarp ten feet high facing in the opposite direction, so that the net displacement is about ten feet. At other points the main scarp is associated with others running nearly parallel and facing in the same direction."[1]

Professor Whitney, in his discussion of the earthquake[2] suggests that such disturbances might have their origin in the compression exercised by an enormous weight of material raised to a vertical height of two or three miles above the surrounding country.

The extent of the tilting of the Inyo Range to the south of Waucobi Canyon is not readily determinable. The eastern face of the range, toward Saline Valley, indicates the presence of a fault line, and the steepness of the slopes near the valley that the faulting is of relatively recent date. On the Owens Valley side the slopes are also steep, but at the mouths of the canyons there are great accumulations of talus that extend far out into the valley, and the monoclinal character of the range is broken by the presence of arching masses of strata of Triassic age, dipping westward.

North of the embayment, along the high, broad mass of the White Mountain Range, no evidence of recent elevation or tilting was observed in the hurried trip through Owens Valley along the western foot of the range.

In a paper now in preparation I shall describe certain types of faulting and tilting of monoclinal blocks of strata that are characteristic of the Great Basin area of Utah, Nevada, and southeastern California. The principal illustrations will be taken from faulted slabs of limestones collected in Waucobi Canyon on the western slope of the Inyo Range, and it is anticipated that they will aid in explaining the dynamics of such a movement as has evidently taken place in that portion of the Inyo Range which is described in this paper.

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[1] Mon. U. S. Geol. Survey, Vol. I, 1890, p. 361.

[2] Loc. cit., p. 276.